Plankton dynamics in Leschenault Inlet and comparisons with the Peel-Harvey estuary

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Abstract

Concerns over weed accumulations on beaches and possible nutrient enrichment prompted an investigation into phytoplankton dynamics of Leschenault Inlet. The composition of the phytoplankton community, its relative density and the amplitude seasonal density changes were investigated over an eighteen month period. The zooplankton community was also sampled during summer to identify dominant organisms.

The phytoplankton community was dominated by marine and estuarine diatoms for most of the year. Species having a freshwater affinity were observed for short periods during winter, and included diatoms, dinoflagellates, cyanophytes and cryptophytes. These species were probably transported into the estuary with winter runoff from streams throughout the catchment. There was a high proportion of normally benthic or epiphytic species in surface waters consistent with very shallow depths and significant wind mixing for much of the year. Some of these species were observed attached to seagrass leaves.

There was considerable spatial and temporal variability in cell densities and species numbers throughout the estuary. Short-term blooms in excess of 5 000 cells mL^{-1} were observed in the estuary during autumn and spring. The presence of blooms indicates that Leschenault Inlet may be experiencing some nutrient enrichment although greater species numbers than observed in the highly nutrient enriched Peel and Harvey estuaries suggest that Leschenault Inlet may only be mildly nutrient enriched. Further investigations into sediment and nutrient inputs and the autecology of phytoplankton indicator species may assist in determining the nutrient status of Leschenault Inlet.

Keywords: phytoplankton, zooplankton, Leschenault Inlet, estuary, south-western Australia.

Introduction

It has been established (Kennish 1994) that estuaries are more productive than fresh water or marine ecosystems. In recent years, southwest Australian estuaries have received excessive loadings of nutrients and have displayed symptoms of increased primary productivity. Nutrient enrichment in some southwest Australian estuaries has lead to: increased phytoplankton density, mostly diatoms (John 1988), although in severe cases, potentially harmful dinoflagellates and cyanophytes have occurred (McComb & Humphries 1992; Hosja & Deeley 1993; Harris 1994); increased growth of submerged macroalgae (Gordon & McComb 1989; Lavery *et al.* 1991); and increased production of opportunistic seagrass species (Lukatelich *et al.* 1987). Excessive growth of opportunistic plant species in estuaries has also caused a loss of seagrasses (McComb & Davis 1993) through smothering by macroalgal blankets (Gordon & McComb 1989; Lavery *et al.* 1991) or through reduced light levels caused by increased epiphyte biomass (McComb & Humphries 1992).

There have been a number of investigations into the magnitude and causes of nutrient exports to southwest estuarine waters and their impact on estuarine primary production (Congdon & McComb 1980; Birch *et al.* 1986; McAlpine *et al.* 1989; Hodgkin & Hamilton 1993; Thompson & Hosja 1996) and it has been established that because of their unique characteristics, estuaries in the southwest of Western Australia are more susceptible to nutrient enrichment than those elsewhere in Australia (Deeley *et al.* 1999).

Southwestern Australian estuaries have been found to be biologically depauperate in their natural condition because of very low levels of nutrients and highly variable salinities mean that faunal assemblages in these estuaries could be expected to have a high proportion of opportunistic species (Deeley & Paling 1998). A high proportion of opportunistic species is a characteristic of anthropogenic disturbance (Warwick 1993) and it may therefore be difficult to detect the impacts of human disturbance in these systems subjected to a high level of natural disturbance (salinity changes).

Weed accumulations on beaches and a concern that nutrient enrichment was causing a decline in the ecological health of the estuary prompted an investigation into phytoplankton dynamics of Leschenault Inlet. The composition of the phytoplankton community, its relative density and the amplitude of seasonal density changes were investigated.

Materials and Methods

For phytoplankton, samples were collected from three sites in the estuary (Fig 1) at intervals of between 7 to 14 days from June 1984 to January 1986. Seagrass leaves were collected in 1998 for assessment of attached microalgae. For zooplankton, samples were collected in January 1996 at 9:00 pm.

Figure 1. Location of phytoplankton sampling sites in Leschenault Inlet.

Sample collection and preservation

For phytoplankton, samples were collected between 8:30 am and 1:00 pm on all occasions. Known volumes of the surface 0.3 m of the estuary water were passed through a 5 micron net to collect phytoplankton cells. The net was rinsed and reversed at each site prior to sample collection to avoid cross contamination between sites. Samples were transferred to pre-labelled 125 ml plastic vials containing 1 ml of Lugol's iodine preservative.

To facilitate phytoplankton identification, samples of live phytoplankton were also collected at the water surface at each site and concentrated by using a phytoplankton net of 5 μm mesh pore size.

For attached phytoplankton, seagrass leaves were scraped with a razor blade and the scrapings placed into a known volume of water. Counts were then undertaken as for the phytoplankton described below. For zooplankton, vertical trawls were undertaken using a 100 μm mesh pore size (*Swiss Screens*). Samples were preserved in formalin for identification counting.

Plankton enumeration and identification

Microscopic examination of the live phytoplankton cells was carried out on the same day of collection using an Olympus BH-2 compound microscope. Some delicate species either readily rupture (*Heterosigma*) or distort (*Gyrodinium*) on preservation, requiring careful interpretation during enumeration.

Phytoplankton cell counting of the preserved cells was undertaken at 125X magnification using a 1 ml volume Sedgewick Rafter counting chamber. A correction factor was applied to allow for the dilution caused by the added preservative. Dilution or concentration techniques were applied to samples when appropriate to facilitate counting.

Some of the smallest and more delicate phytoplankton species such as the diatoms *Rhizosolenia*, *Chaetoceros* and the chrysophyte, *Pseudopedinella*, were counted using a higher magnification by leaving the coverglass off, allowing the cells to settle, and the water to partially evaporate. This permitted the observation of cells at a higher magnification (250X) by facilitating the use of the (20X) objective lens of the microscope.

Zooplankton cell counting of the preserved cells was undertaken at 125X magnification using a 1 ml volume Sedgewick Rafter counting chamber. A correction factor was applied to allow for the dilution caused by the added preservative. Dilution or concentration techniques were applied to samples when appropriate to facilitate counting.

Results

Phytoplankton species observed during summer (December–February) show that diatoms were dominant in Leschenault Inlet with lesser numbers of dinoflagellates, cyanophytes and cryptophytes (Table 1). Around 50% of species observed in the surface 0.3 m of the estuarine waters are normally considered to be benthic or epiphytic (Table 1) and this is consistent with the very shallow (mean depth 0.7 m) wind-mixed nature of the estuary.

The total number of phytoplankton cells observed at sites 1, 3 and 4 (Fig 2) show that cell densities were low at between 4 to 100 cells mL^{-1} for much of the observation period. Cell densities at all sites in winter 1984 at below 10 cells mL^{-1}, were lower than for the same sites in winter 1985 when cell densities were mostly above 10 cells mL^{-1}. There was one occasion in 1984 when cell densities at site 3 exceeded 800 cells mL^{-1}.

For 1985, cell densities were between 10 and 1 000 cells mL^{-1} for most of the year except for March and September when blooms (>1 000 cells mL^{-1}) of diatoms were observed. At site 1, cell densities during the bloom of 7th March reached 4 500 cells mL^{-1}. Cell densities at site 3 on the 7th March 1985 reached 7 000 cells mL^{-1}, and during a second bloom later in the year on the 5th September 1985 reached 10 600 cells mL^{-1}. There were periods when the cell densities at sites 1 and 3 were similar and other times when they were quite different. The blooms of the 7th March and the 5th September show that on the first occasion, sites 1 and 3 had similar cell densities while on the second occasion there was no relationship between the two sites.

The blooms observed at sites 1 and 3 were short-lived and numbers had returned to normal levels within 2 weeks of the peak densities being observed. Cell densities closest to the ocean were considerably less than those observed at the other two sites. There were no blooms observed at site 4.

The composition of phytoplankton species at site 3 (Fig

Table 1. List of phytoplankton species observed during summer (December-February).

Subclass	Order	Family	Cells mL^{-1}	Abundance[a]	Epi/Benthic[b]
Centrales	Asterolampraceae	Asterolampraceae	*Eucampia* sp 1	1	Y
Centrales	Biddulphiales	Biddulphiaceae	*Cerataulina cf pelagica*	2	N
Centrales	Coscinodiscineae	Melosiraceae	*Skeletonema costatum*	3	N
Centrales	Rhizosoleniaceae	Rhizosoleniaceae	*Rhizosolenia setigera*	3	N
Centrales	Rhizosoleniaceae	Rhizosoleniaceae	*Rhizosolenia stolterfothii*	2	N
Centrales	Rhizosoleniaceae	Rhizosoleniaceae	*Guinardia* sp 1	2	N
Centrales		Chaetoceraceae	*Chaetoceros perpusillum*	3	Y
Centrales		Chaetoceraceae	*Chaetoceros peruvianum*	1	N
Centrales		Chaetoceraceae	*Chaetoceros didymum*	3	N
Centrales		Chaetoceraceae	*Chaetoceros cf contortum*	1	N
Centrales		Chaetoceraceae	*Chaetoceros straightout*	3	N
Centrales		Chaetoceraceae	*Chaetoceros sociale/radians*	2	N
Centrales		Chaetoceraceae	*Chaetoceros* sp 3	2	N
Centrales		Chaetoceraceae	*Chaetoceros* sp 4	3	N
Centrales		Melosiraceae	*Paralia sulcata*	2	Y
Centrales		Lithodesmiaceae	*Lithodesmium undulatum*	2	N
Centrales		Heliopeltaceae	*Actinoptychus*	1	Y
Centrales		Coscinodiscaceae	*Thalassiosira* sp 1	2	N
Centrales		Coscinodiscaceae	*Thalassiosira* sp 2	2	N
Pennales	Achnanthales	Acnanthaceae	*Cocconeis* sp 1	1	Y
Pennales	Auriculaceae	Auriculaceae	*Surirella patricicae*	1	Y
Pennales	Bacillariales	Nitzschiaceae	*Nitzschia closterium*	3	N
Pennales	Bacillariales	Nitzschiaceae	*Nitzschia longissima*	2	Y
Pennales	Bacillariales	Nitzschiaceae	*Pseudonitzschia* sp1	2	N
Pennales	Bacillariales	Nitzschiaceae	*Pseudonitzschia* sp2	2	N
Pennales	Bacillariales	Nitzschiaceae	*Pseudonitzschia* sp3	2	N
Pennales	Bacillariales	Nitzschiaceae	*Bacillaria paxillifera*	1	Y
Pennales	Bacillariales	Nitzschiaceae	*Nitzschia punctata*	2	Y
Pennales	Bacillariales	Nitzschiaceae	*Nitzschia triblionella*	1	Y
Pennales	Bacillariales	Nitzschiaceae	*Nitzschia* sp 3 vvs	2	Y
Pennales	Bacillariales	Nitzschiaceae	*Nitzschia cf linearis*	1	Y
Pennales	Fragilariales	Fragilariaceae	*Asterionellopsis glacialis*	2	N
Pennales	Fragilariales	Fragilariaceae	*Gramatophora oceanum*	2	N
Pennales	Fragilariales	Fragilariaceae	*Licmophora paradoxa*	1	Y
Pennales	Fragilariales	Fragilariaceae	*Licmophora flabellata*	1	Y
Pennales	Fragilariales	Fragilariaceae	*Licmophora lynghyei*	1	Y
Pennales	Fragilariales	Diatomaceae	*Synedra* sp 2 med	1	Y
Pennales	Fragilariales	Diatomaceae	*Thalassionema nitzschiodes*	2	N
Pennales	Fragilariales	Diatomaceae	*Synedra*	2	-
Pennales	Fragilariales	Fragilariaceae	*Striatella unipuridata*	2	Y
Pennales	Naviculales	Cymbellaceae	*Amphora* sp1	1	Y
Pennales	Naviculales	Cymbellaceae	*Amphora hyalina*	1	Y
Pennales	Naviculales	Entomoneidaceae	*Entomoneis* sp 2	1	-
Pennales	Naviculales	Entomoneidaceae	*Entomoneis* sp 3	1	-
Pennales	Naviculales	Naviculaceae	*Mastogloia* sp 1	1	Y
Pennales			*Pennate* sp 1	2	Y
Pennales		Auriculaceae	*Surirella*	2	Y
		Leptocylindraceae	*Leptocylindrus danicus*	2	N
		Leptocylindraceae	*Leptocylindrus minimus*	1	N
	Prorocentrales	Prorocentraceae	*Prorocentrum minimum*	1	N
	Prorocentrales	Prorocentraceae	*Prorocentrum gracile*	1	N
	Dinophysales	Dinophysaceae	*Dinophysis caudata*	1	N
	Peridinales	Ceratiaceae	*Ceratium furca*	1	N
	Peridinales	Ceratiaceae	*Ceratium lineatum*	1	N
	Gymnodinales	Gymnodinaceae	*Gyrodinium spirale*	1	N
			Scrippsiella	2	N
	Peridinales	Gonyaulaceae	*Gonyaulax grindleyi*	1	N
	Peridinales	Gonyaulaceae	*Gonyaulax* sp 1	2	N
	Peridinales	Gonyaulaceae	*Alexandrium minutum*	1	N
	Peridinales	Peridinaceae	*Protoperidinium pellucidum*	2	N
	Peridinales	Peridinaceae	*Protoperidinium bipes*	2	N

Table 1 Continued. List of phytoplankton species observed during summer (December-February).

Subclass	Order	Family	Cells mL^{-1}	Abundance[a]	Epi/Benthic[b]
	Peridinales	Peridinaceae	*Protoperidinium claudicans*	2	N
	Peridinales	Peridinaceae	*Heterocapsa triquetra*	2	N
	Peridinales	Peridinaceae	*Ensiculifera*	1	N
			Katodinium	1	N
			Eutreptiella	2	N
	Cryptophyceae	Pedinales	*Apedinella*	2	N

[a] 1: Rare, 100 cells mL^{-1}; 2: Present, 100 - 1 000 cells mL^{-1}; 3: Abundant, ^{3} 1 000 cells mL^{-1}.
[b] Species normally benthic or epiphytic (Y) or not (N).

Table 2. List of species of attached microalgae observed on seagrass leaves.

Site	Abundance[a]	*Acnanthes*	*Cocconeis*	*Gramato -phora*	*Gyrosigma*	*Mastogloia* spp	*Paralia sulcata*	*Synedra* spp	Others
North of Site 4	2	3	2			3			
East of Site 3	2		1	2	2	2		3	
Site 3	2		3	3		2	2		
West of Site 3	2		1	3		2	3	3	
East of Site 1	3			1		3		3	
Site 1									
West of Site 1	2		3	2		2	3	1	

[a] 1: rare, 100 cells blade^{-1}; 2: present, 100-500 cells blade^{-1}; 3: abundant, ^{3} 500 cells blade^{-1}

3) shows that the phytoplankton community was dominated by diatoms which comprised more than 50% of the phytoplankton community from June 1984 to October 1985. From November 1985 to January 1986, dinoflagellates were dominant at more than 60% of the community. Cyanophytes and cryptophytes were most abundant during winter (April to August) and were associated with fresh water inputs from the catchment. Cryptophytes increased to 15% of the community on the 24th June 1985.

The number of phytoplankton species at each site ranged from 15 to 60 (Fig 4). Species numbers were greatest in winter and spring and reached a minimum on the 15th November 1984 and on the 16th January 1986. On most occasions, numbers of species were greatest for site 4 closest to the ocean and least at site 1 furthest from the ocean. There was a period from the 24th July 1985 until the 12th December 1985 when there were fewer species at site 3 than were observed at site 1.

Comparisons with phytoplankton communities averaged over all sites for the Peel and Harvey estuaries (Fig 5) showed on most occasions there were a greater number of species in the Leschenault Inlet than were observed in either the Peel or Harvey estuaries. The reduction in the number of species observed in Leschenault over summer

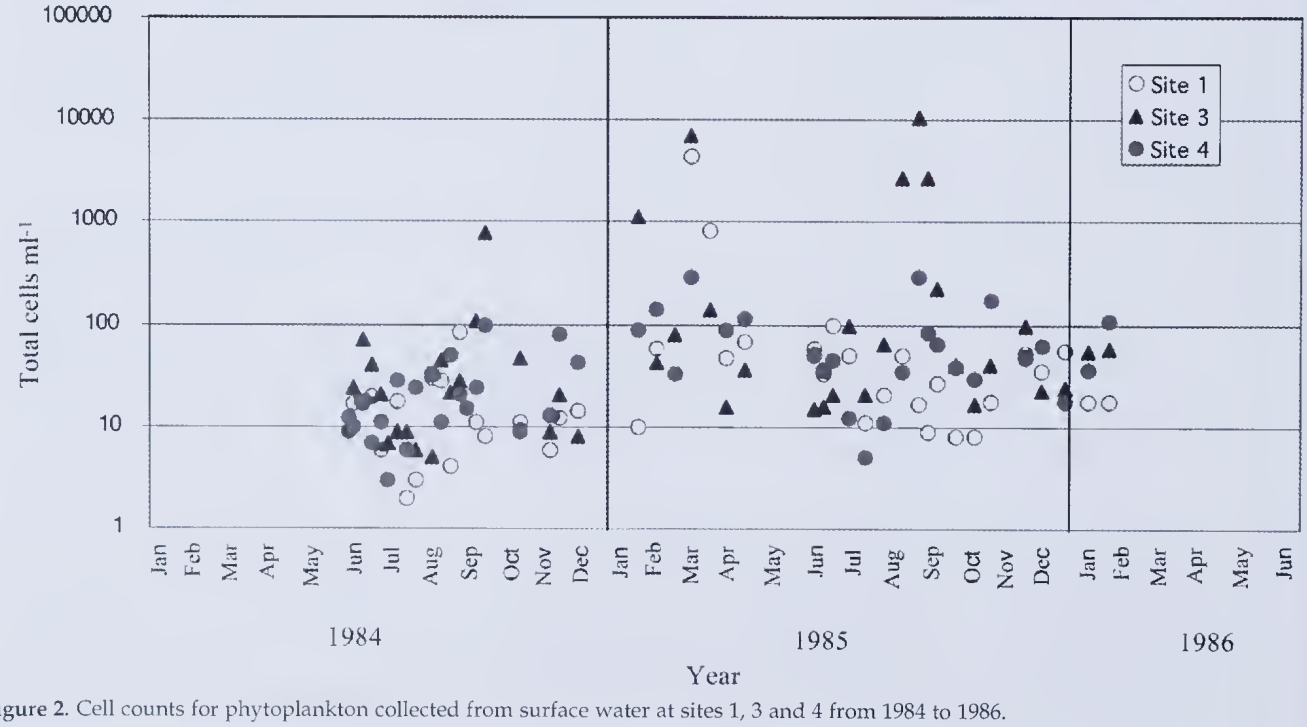

Figure 2. Cell counts for phytoplankton collected from surface water at sites 1, 3 and 4 from 1984 to 1986.

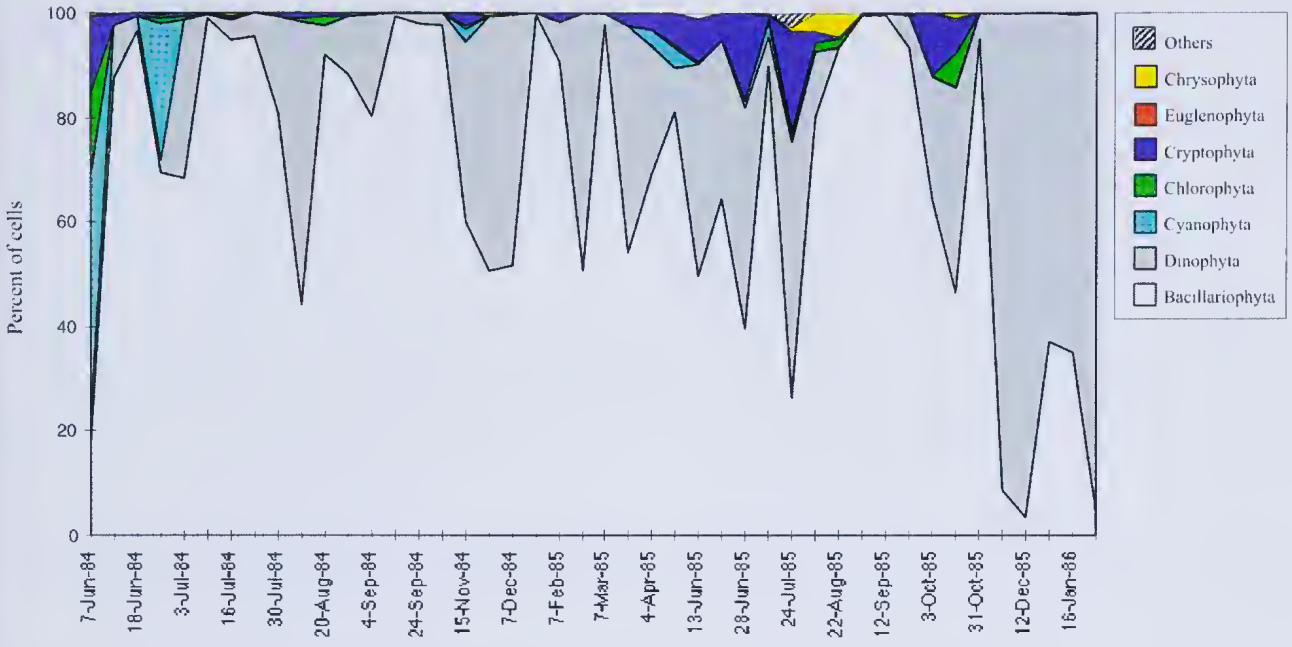

Figure 3. Composition of the phytoplankton community collected from surface water at site 3 from 1984 to 1986.

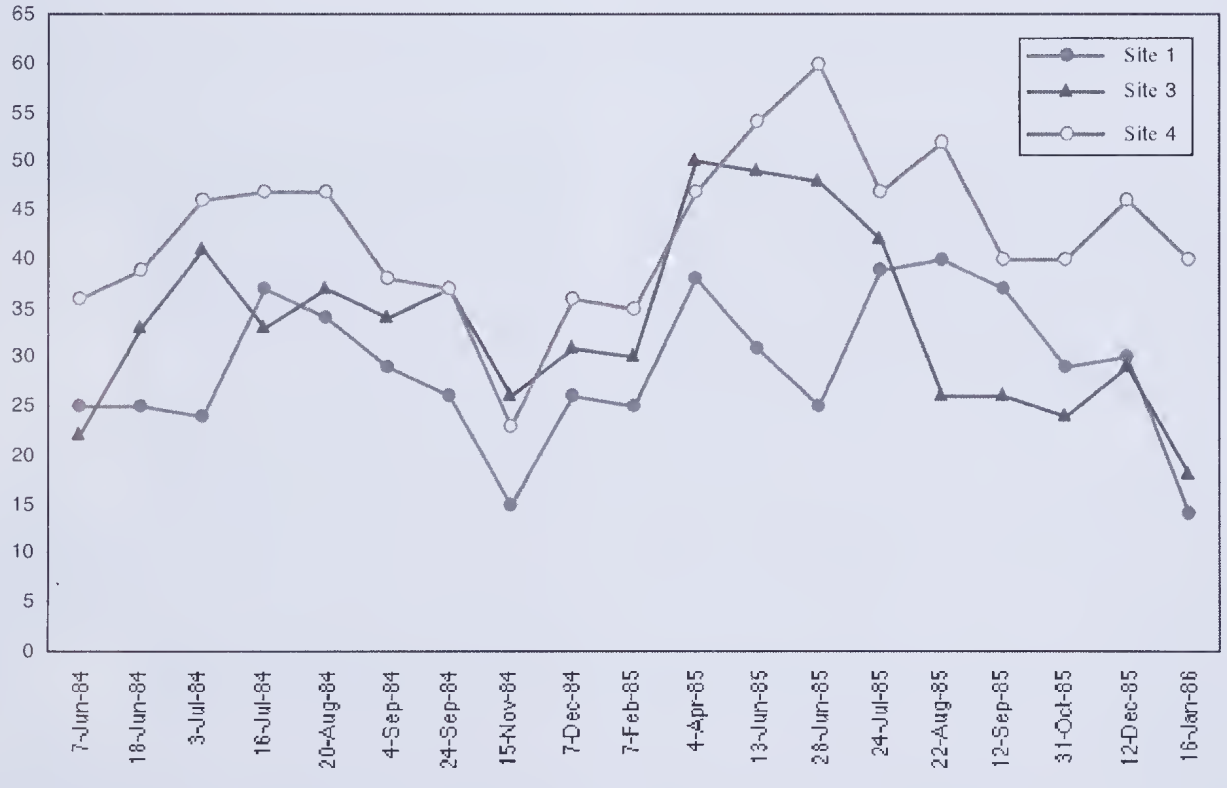

Figure 4. Number of phytoplankton species collected from surface water at sites 1, 3 and 4 from 1984 to 1986.

was also observed in the Peel and Harvey estuaries.

The attached microalgae observed on seagrass leaves (Table 2) showed similar densities to those observed in the water column (Table 1). There were many species that were identified as normally being epiphytic or benthic that were not observed on seagrass leaves. This is because benthic species which live in soft sediments would not normally be present as epiphytes on seagrasses.

Zooplankton observed in the estuarine waters during summer at night showed that 5 species were abundant having numbers in excess of 500 per vertical trawl (Table 3). There was a total of 15 zooplankton species compared to up to 60 phytoplankton species.

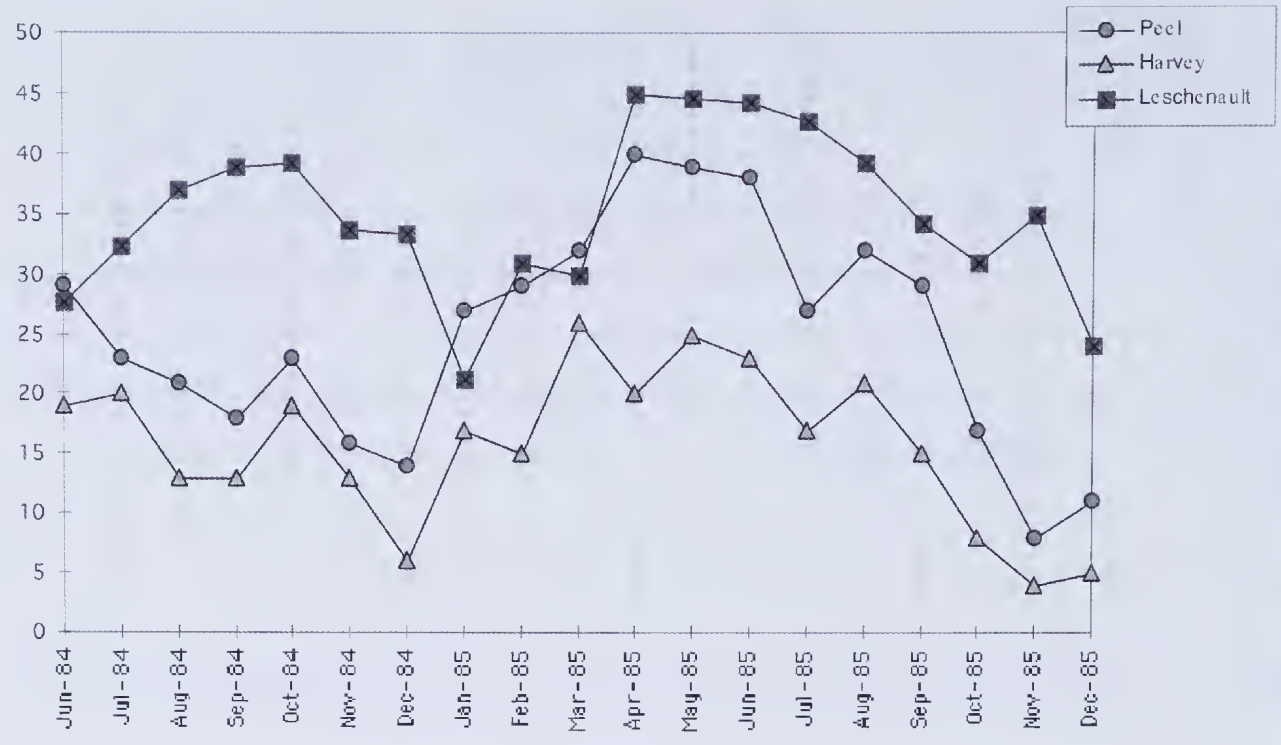

Figure 5. Average number of phytoplankton species from surface water in the Peel, Harvey and Leschenault inlets from 1984 to 1986.

Discussion

The phytoplankton community of Leschanualt Inlet was dominated by marine and estuarine diatoms for most of the year although freshwater diatoms and other groups were observed for short periods during winter. Phytoplankton species having an affinity with fresh conditions may have been transported into the estuary in winter runoff from rivers and streams further up in the catchment. Leschenault Inlet extends north south and its major axis is aligned with the prevailing southwesterly summer breezes. This means that the inlet is well-mixed for much of the year. The degree of wind mixing, together with a shallow mean depth of 0.7 m, has lead to the surface phytoplankton community containing around 50% of species normally considered to be benthic or epiphytic. These normally attached species are probably being constantly removed from substratum and entrained in the water mass where they remain for some time.

Table 3. List of zooplankton species observed during summer (December-February).

Species	Abundance[a]
Sulcanus conflictus	1
Acartiura	3
Cyclopoid sp 1	3
Cyclopoid sp 2	3
Cyclopoid sp 3	2
Copepod 1	1
Copepod 2	1
Calanoiod sp 1	2
Calanoiod sp 2	2
Hapacticoid sp 1	3
Hapacticoid sp 2	2
Hapacticoid sp 3	2
Polychaete Larvae	2
Naupius larvae	3
Malacostraca	2

[a]1: rare, ≤ 100 cells trawl^{-1}; 2: present, 100-500 cells trawl^{-1}; 3: abundant, ³ 500 cells trawl^{-1}.

There were seasonal and temporal patterns in the distribution of phytoplankton species with occasional short-term blooms at some sites in excess of 5 000 cells mL^{-1}. The site closest to the ocean had the least seasonal variability in its phytoplankton community and the lowest number of species. The site most distant from the ocean had the highest number of species, and here a bloom was observed on one occasion. The site intermediate between the two had the highest cell densities, an intermediate number of species and blooms were observed on more than one occasion. These observations were consistent with a higher level of productivity in estuaries than in marine areas (Kennish 1994).

It was not possible to draw definitive conclusions as to whether the large fluctuations in cell densities at site 3 were a symptom of nutrient enrichment but blooms of this density have been associated with nutrient enrichment in other settings (Harris 1994). Comparisons with Peel and Harvey estuaries indicated that Leschenault had a higher number of species than these two estuaries that have been recognised as being highly nutrient enriched. A reduction in species richness has been associated with anthropogenic disturbance elsewhere (Patrick & Palavage 1994) and a greater number of species may indicate that Leschenault Inlet was less nutrient enriched than either Peel or Harvey estuaries.

An investigation into the autecology of particular indicator species may provide additional information on the nutrient status of Leschenault.

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